ELECTRON LINAC PRODUCTION OF CO-57 FOR GAMMA-CHAMBER CALIBRATION

N.P. Dikiy, N.A. Dovbnya, O.A. Repikhov, I.N. Shlyakhov, V.L. Uvarov, Ja.N. Kravchenko[1]
National Science Center "Kharkov Institute of Physics and Technology",
61108, Kharkov, Ukraine
uvarov@kipt.kharkov.ua
[1] *Kharkov Institute of Metrology,*
61002, Kharkov, Ukraine

Gamma-chambers are widely used in medicine diagnostics to obtain an organ image investigated by means of the scintigraphy method. A radionuclide Tc-99m which is accumulated in the organ and irradiates photons with the energy E_γ=140 keV is a carrier of the information. Ukraine manufactures gamma-chambers of own elaboration. A γ-source with a photon energy of Tc-99m but with a larger half-life time is need for their plant calibration. The Co-57 sources (E_γ=122 keV, $T_{1/2}$=270 days) are the most eligible for this purpose. Their traditional technology is based mainly on the reactor method and is accompanied by the large amount of the radioactive waste. The sources, obtained in such a way, can not be regenerated after their decay. The R&D Complex "Accelerator" of the NSC KIPT developed a new technology and manufactured the model – experimental batch of three Co-57 sources using bremsstrahlung of the high-current electron linac. The Co-57 generation processes in the Ni-58 target were previously investigated by means of computer simulation. The optimum accelerator operation regime and a target geometry were thus determined. The obtained sources characteristics confirmed the computer analysis data. Each of them is the plate of 28x28x1.5 mm and has the activity up to 2 mCi. The spectrum of the source measured with the Ge(Li) detector satisfies all demands. The technology developed provides a production of sufficient amount of Co-57 sources practically without any waste, as well as, a possibility of their regeneration.
PACS number: 07.85.Fv

1 INTRODUCTION

One can produce a Co-57 isotope by means of nickel irradiation with high-energy photons along two reaction channels:

$^{58}Ni(\gamma,p)^{57}Co$ (Q=-8.178 MeV, σ_{max}=7.0 mb, $E_{\gamma max}$=20 MeV);

$^{58}Ni(\gamma,n)\,^{57}Ni \rightarrow {}^{57}Co$ (Q=-12.204 MeV, σ_{max}=23 mb, $E_{\gamma max}$=18 MeV);

Because the cross-sections of these reactions are comparatively low there is need to solve a problem of concentration of the powerful (≥10 kW) radiation flux into the converter & target setup with ensuring corresponding cooling of their elements for the Co-57 production with an acceptable specific activity (≥10^{-3} Ci/g). So, a choice of the target device geometry and its irradiation regime is determined by optimization of such parameters as electron energy, thickness of the converter, target and cooling water layers as well as a Co-57 generation efficiency (i.e. the yield of the Co-57 nucleuses per one accelerated electron).

2 COMPUTER SIMULATION

A 2D-model based on the GEANT code was elaborated for investigation of the Co-57 generation in the natural Ni-target (that contains up to 68 % of Ni-58 isotope) – [1]. The model considers a converter of a real composition which includes an Al-casing and two 1.2 mm Ta-plates each cooling with water. The target is considered as an infinite 10 mm thick plate.

The energy losses in each element of the setup were calculated for 3 values of the electron energy (15, 20, 25 MeV) as well as a daily production of the Co-57 for beam power as much as 1 kW (see Table 1).

Table 1. Results of computer simulation

	Electron energy, MeV		
	10	**15**	**20**
Electron energy flux, kW	15	20	25
Co-57 activity, MBq/kW· ·beam·day			
in reaction: $^{58}Ni(\gamma,p)^{57}Co$	1.26	9.68	20.86
$^{58}Ni(\gamma,n)\,^{57}Ni \rightarrow {}^{57}Co$	0.86	28.57	65.53
Distribution of the energy losses in the setup, W/kW_{beam}			
Ta-plates	703	601	508
water	73	75	70
Ni-target	77	135	200

An analysis of the table data shows that an increase of the electron energy is accompanied both by essential rise of the Co-57 yield and some leveling of distribution of the radiation energy losses in the converter and target elements. At the same time a further increase of the electron energy is accompanied by appearance of the undesirable ("background") isotopes generation which deteriorates a radiation spectrum of the final product.

3 EXPERIMENT

The target setup for experimental production of Co-57 was assembled at the LU-20 Linac [2] – see Fig. 1.

The aluminium casing **1** contains the cassette **4** (aluminium net) in which two tantalum plates **2** (converter) are placed divided with 3 mm water layers as well as the 1.5x28x84, mm nickel plate (target). The latter consists of three lightly separated parts (28x28 mm). The casing is supplied with two butt-end flanges which provide a hermetic packing of the setup elements cooling with running water under target irradiation.

During a Co-57 generation the accelerator was operating in the regime:

electron energy, MeV	-	28
average beam current, μA	-	530
pulse current, mA	-	670
beam pulse repetition rate, Hz	-	150

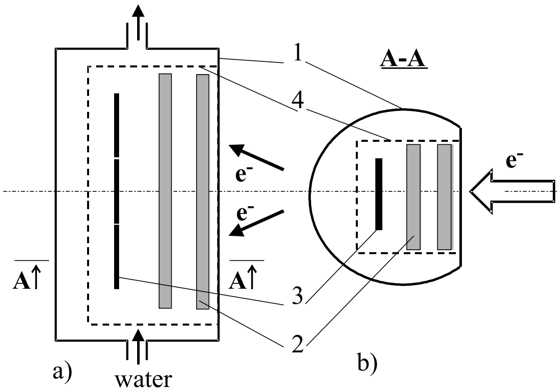

Fig. 1. Target setup: a – lateral view, b – cross-section.

A beam was continuously scanned also with 3 Hz frequency in the vertical plane for uniform distribution of the heat loading within the exit window of the accelerator and target elements. The radiation treatment of the target lasted 100 hours. Then, after 20 days exposure into a depository (for decay of the short-lived “background” isotopes) an experimental sample of the source was placed into the specially designed shield block (Fig. 2).

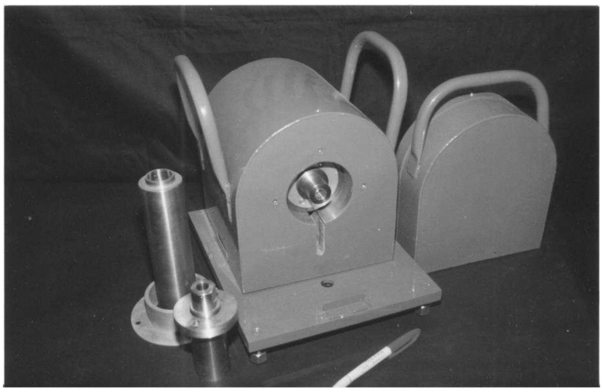

Fig. 2. Co-57 source into shield block with a set of collimators.

4 METROLOGICAL INVESTIGATION

4.1. The gamma-chamber calibrator (later on “calibrator”) thus obtained consists of the radioactive Co-57 source placed into the shield block and supplied with the 9°-collimator. The calibrator provides a radiation field within certain region (“working region”) with the necessary characteristics.

4.2. The purpose of the metrological investigation was a determination of the next calibrator characteristics:

- Co-57 source activity;
- radiation energy spectrum;
- relative distribution of the EDR within working region of the calibrator;
- EDR distribution outside the working region.

4.3. Conditions and results of the measurements.

4.3.1. A measurement of the Co-57 source activity was carried out by means of comparison of the pulse rate count at the exit of the semiconductor spectrometer supplied with the Ge(Li) detector in a certain energy range including the Co-57 photopeak (122 keV) from an investigated source and from the working standard Co-57 source which has a known activity and is placed at the same distance from the detector.

4.3.2. A measurement of the energy spectrum (Fig. 3) was fulfilled using the same Ce(Li) detector.

4.3.3. A measurement of the EDR distribution within a working region of the calibrator was carried out by means of its placement at the distance 2300 mm from the measurement plane and determination of the pulse rate count at the exit of the TX 201AP semiconductor detector. The latter has the characteristics:

sensor type	-	CdTe
size of monocrystal, mm	-	5x5x2
bias voltage, V	-	39
background noise, keV	-	≤10
number of analyzer channels	-	4096
maximum of measuring tract load, s^{-1}	-	150

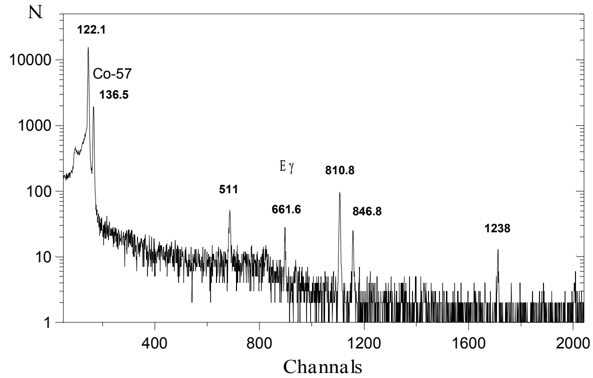

Fig. 3. γ-radiation spectrum of the Co-57.

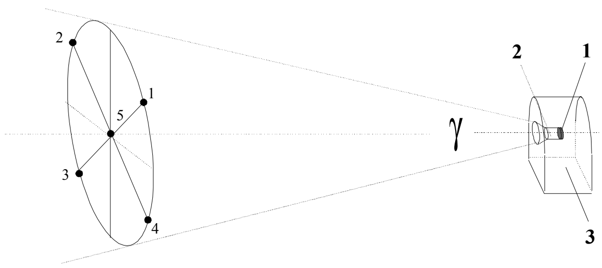

Fig. 4. Schematic diagram of measurement points of the calibrator working region.

The detector TX 201 AP was placed in turn in each of five measurement points of the working region (Fig. 4). The exposure time in one point was 300 s. The pulses with amplitude corresponding to the energy range 60...140, keV and the pulses outside this range were calculated separately (see Table 2).

Table 2. Results of the calibrator working region investigation

N of measur. Point	Counts number (60...140,keV)	Counts number, total
1	11600	
2	11644	
3	11612	
4	11626	
5	11658	24668

4.3.4. A distribution of the EDR outside the working region was carried out by means of placement of the DRG 3-02 dosimeter in a measurement point. The obtained data showed that the EDR value on a surface of the shield block with closed lid and plugged collimator - ≤360 μR/hr

at a distance 10 cm from the block surface - ≤300 μR/hr

at a distance 40 cm from the block surface - ≤30 μR/hr

4.3.5. An investigation of the EDR distribution along the calibrator axes was carried out in the points that are shown in Fig. 5.

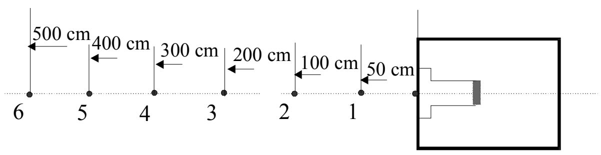

Fig. 5. Scheme of the EDR measurement along the calibrator axes.

Table 3. EDR value along the calibrator axis

N of measur. point	EDR, μR/hr
1	2200
2	720
3	310
4	140
5	70
6	30

5 CONCLUSIONS

1. A technology for calibrator of the gamma-camera production is elaborated. The technology is based on using the bremssrahlung radiation of the high-current electron accelerator.
2. The electron energy range 25...30 MeV seems to be optimal for the Co-57 isotope generation in the Ni-target.
3. The technology provides a Co-57 receipt as a closed type radiation source with a possibility of its multiple regeneration.
4. The calibrator produced under a new technology has the next metrological parameters and characteristics:

Co-57 source activity, mCi - 2

energy of the main γ-radiation line, keV - 122
main co-product - Co-58
energy of the main co-product radiation line, keV - 810
relative activity of the co-product (normalized to activity of the main Co-57 line), % - <1
distance from the source to the working region plane, mm - 2300
exposure dose rate within the working region, μR/hr - 300
main error of the source activity measurement (P=0.95), % - ≤20
main error of the EDR measurement within the working region (P=0.95), % - ≤15

The experimental prototype of the calibrator was certificated in the Kharkov Institute of Metrology.

Work is supported by STCU under contract N 2185.

REFERENCES

1. N.P.Dikiy, A.N.Dovbnya, S.V.Maryokhin, V.L.Uvarov. On Efficiency of Medical & Biophysical Isotopes Production Using Electron Accelerator // *Problems of Atomic Science and Technology. Issue: Nucleatr-Physics Research* (34). 1999, v. 3, p. 91-92.
2. A.N.Dovbnya et al. Electron Linacs Based Radiation Facilities of Ukrainian National Science Center “KIPT” // *Bull. of Amer. Phys. Soc*. 1997, v. 42, # 3, p. 1391.